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THE
DESIGNERS'
GUIDE
FOR
SPECIFYING
OSCILLATORS

accutronics, inc.

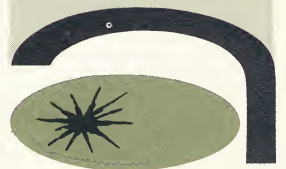


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THE DESIGNERS' GUIDE FOR SPECIFYING OSCILLATORS

Every electronic engineer, at one time or another, has been exposed to oscillator theory. Therefore, this book does not deal with the very deep theoretical aspect of oscillator design, but rather with the utilization and implementation of oscillators to applicable instruments and systems.

One purpose of this book is to provide a sound background in present day oscillator manufacturing practice and flexibility. The varieties of characteristics concerning crystal, tuning fork, LC, and RC oscillators will be explained and provide detailed information and specifications which are not easily obtained by those who are not specialists in oscillator design and application.

Another purpose of this book is to pro-

vide electronic engineers, who are called upon to specify an oscillator for an intended application, a guideline to specifying oscillators. A detailed look at important "everyday" oscillator parameters is given and a comprehensive oscillator specification sheet is covered in detail.

The final purpose of this book is to illustrate, to systems and instrument engineers, that oscillator manufacturers are versatile in providing not only the frequency sources but also portions of the overall circuitry making up the equipment. Illustrations of typical oscillator and oscillator-system interface circuitry will be explained, demonstrating what can be done in this area.

CRYSTAL OSCILLATORS

The crystal oscillator is the most common type of oscillator in use today. The frequency range covered by crystal oscillators extends from less than 1KHz to in excess of 100MHz. In most cases, however, the lower end of the range is restricted to 16KHz because of the poor mechanical as well as electrical stabilities existing below this frequency.

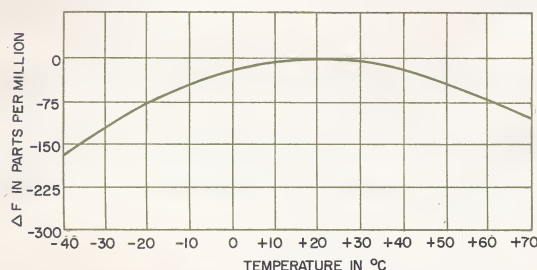
Frequency tolerances vary widely over the frequency range mentioned above. A typical 1KHz crystal oscillator may deviate $\pm 0.03\%$ when subjected to a temperature range of -40°C to $+70^{\circ}\text{C}$. On the other hand, a typical 3MHz crystal will exhibit a $\pm 0.0025\%$ frequency deviation when subjected to the same temperature range. Figure 1 illustrates typical frequency versus temperature curves for crystal units from 1KHz to 100MHz. It should be noted that better temperature characteristics exist for crystals above approximately 800KHz with the best stabilities occurring in the range of 3MHz to 5MHz. Figure 1 also illustrates the different types of cuts useful in their optimum frequency ranges. When specifying crystal oscillators, do not give frequency tolerance as a temperature coefficient since the curves in Figure 1 are non-linear.

When a low frequency crystal oscillator is to be used in an application where shock and vibration are present, the oscillator manufacturer should be informed since low frequency crystal units are particularly subject to damage or out of tolerance operation. These effects are predominant in the approximate range of 1KHz to 15KHz.

The graph in Figure 1, Section F contains three curves. Curve A illustrates the general characteristic of an AT cut crystal. Curves B and C illustrate how the general characteristics can be modified by a slight change in the angle of crystal cut. Curve B illustrates the minimum change in frequency obtainable over a wide temperature range. Curve C indicates that practically a zero temperature coefficient is possible in the range of 0°C to 50°C .

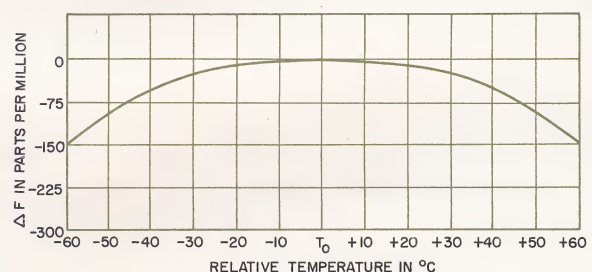
By choosing one of these cuts a crystal oscillator manufacturer is capable of providing a wide range of frequency tolerance.

Figure 1



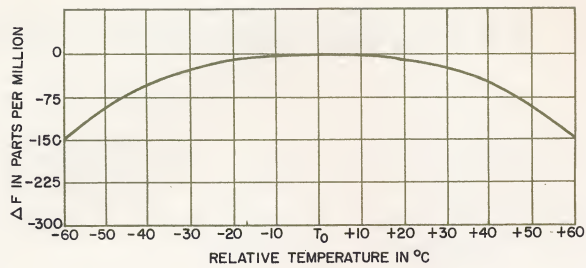
(A.)

Crystal Oscillator using "J" Plate Crystal
 Frequency Range 800Hz to 12KHz
 Frequency Tolerance $\pm 0.05\%$ to $\pm 0.015\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$



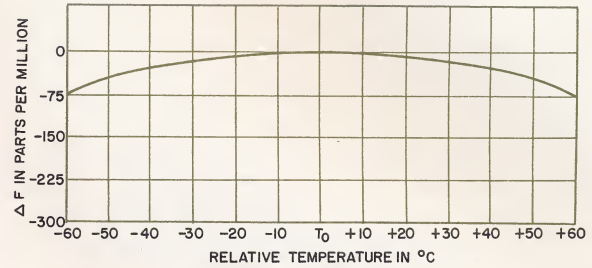
(B.)

Crystal Oscillator Using "XY" Flexure Bar Crystal
 Frequency Range 1KHz to 50KHz
 Frequency Tolerance $\pm 0.025\%$ to $\pm 0.02\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$



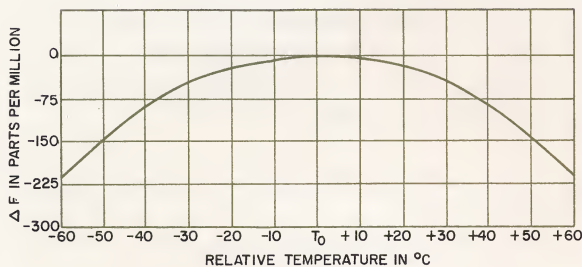
(C.)

Crystal Oscillator Using NT Cut Crystal
 Frequency Range 10KHz to 130KHz
 Frequency Tolerance $\pm 0.012\%$ to $\pm 0.01\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$



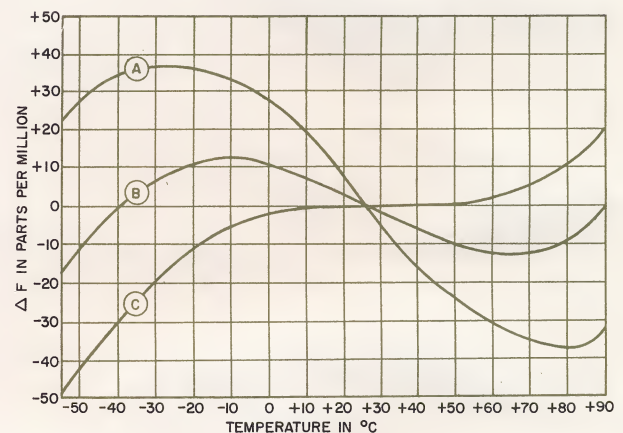
(D.)

Crystal Oscillator Using DT Cut Crystal
 Frequency Range 75KHz to 500KHz
 Frequency Tolerance $\pm 0.01\%$ to $\pm 0.0075\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$



(E.)

Crystal Oscillator Using CT Cut Crystal
 Frequency Range 300KHz to 800KHz
 Frequency Tolerance $\pm 0.02\%$ to $\pm 0.01\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$



(F.)

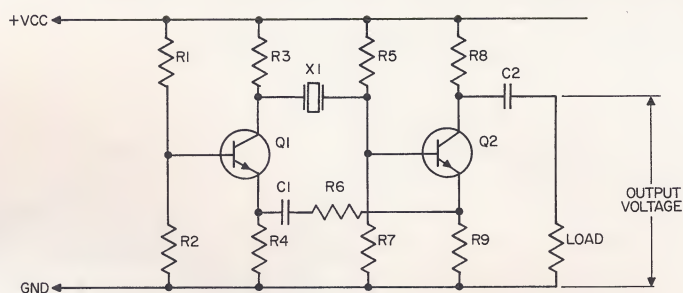
Crystal Oscillator Using AT Cut Crystal
 Frequency Range 600KHz to 100MHz
 Frequency Tolerance $\pm 0.0015\%$ to $\pm 0.001\%$
 Temperature Range -40°C to $+70^{\circ}\text{C}$

A typical 20KHz, NT cut, crystal can sustain vibration of approximately 20G's from 10Hz to 2000Hz. When shock and vibration are a factor involved in a tolerance specification, the oscillator manufacturer normally uses a crystal of a higher frequency and divides down to the required frequency, since higher frequency crystals are capable of sustaining greater shock and vibration specifications exceeding 50 to 100G.

Where a tolerance of better than the basic crystal unit is required, the normal design procedure is to use a crystal oven. However, oven use increases the total power consumption required by the device. Typical thermostatically controlled crystal ovens require approximately 15 watts while some of the more popular proportional control crystal ovens are much more efficient with a typical power consumption of two to five watts. Using ovens which are thermostatically controlled, frequency stabilities to the order of one part in 10^8 can be obtained. When using proportional control ovens, stabilities to the order of three parts in 10^{12} have been produced.

Another efficient way of achieving good tolerances is to temperature compensate the oscillator. As can be seen from Figure 1 the AT cut crystal exhibits an "S" shaped curve for its frequency versus temperature characteristics. In order to temperature compensate this curve and thereby achieve an essentially linear characteristic, a non linear temperature dependent resistance network is designed to supply a correction voltage to a voltage sensitive capacitor in the oscillator. The voltage produced change in capacitance results in a change in frequency in opposition to that of the crystal unit. The algebraic difference between the two frequency effects is the net compensation. When using temperature compensation, it is possible to achieve stabilities to the order of one part in 10^6 . These changes occur with the oscillator subjected to a temperature range of -40°C to $+70^{\circ}\text{C}$.

Typical Crystal Oscillator Circuits

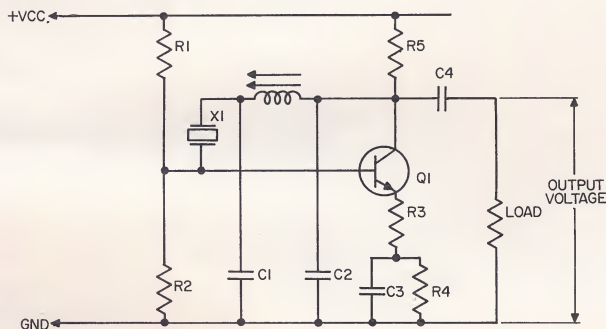


Very Low Frequency Crystal Circuit

Specifications

Frequency Range	1KHz to 200KHz
Frequency Tolerance	$\pm 0.06\%$ to $\pm 0.0075\%$
Temperature Range	-40°C to $+70^{\circ}\text{C}$

In the very low frequency crystal oscillator area the crystals employed are usually operated in their series mode. Low frequency crystals have a large series resistance, therefore, in order to achieve a circuit gain greater than unity the circuit above is employed. The circuit gain is essentially R^3 divided by R^4 (assuming $R_{X1} \gg R^3$) multiplied by a constant. Other means are available to the oscillator manufacturer whereby only one state of active gain is necessary, but the circuit shown is usually more reliable.



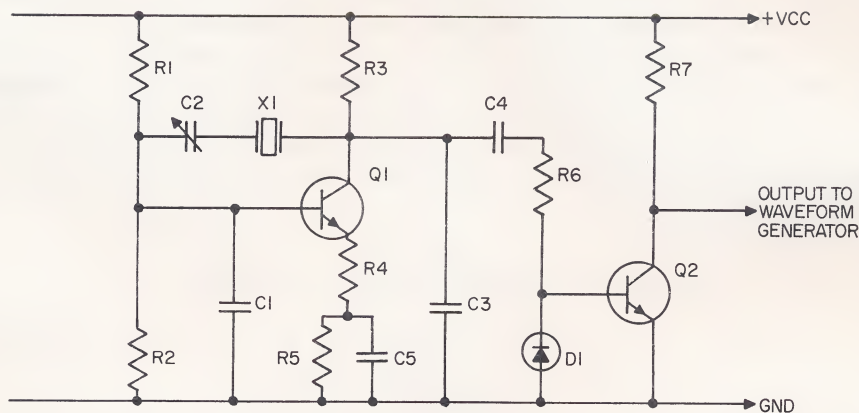
Low Frequency Crystal Circuit

Specifications

Frequency Range	200KHz to 800KHz
Frequency Tolerance	$\pm 0.01\%$ to $\pm 0.005\%$ depending on crystal unit employed
Temperature Range	-40°C to $+70^{\circ}\text{C}$

This circuit is commonly employed in the range specified. The purpose of the pi network is to allow a negative transfer function to be inserted in the positive feedback path permitting the voltage at the output of the network to be in phase with the collector voltage. Since the circuit will oscillate at the point of maximum gain a crystal is placed between the pi network and the transistor. At series resonance the gain between the output of the network and the collector of the transistor will be at a maximum and the circuit will oscillate at this point. Design again involves computation of circuit gain taking into account the losses in the pi network as well as use of a "worst case" crystal.

Typical Crystal Oscillator Circuits

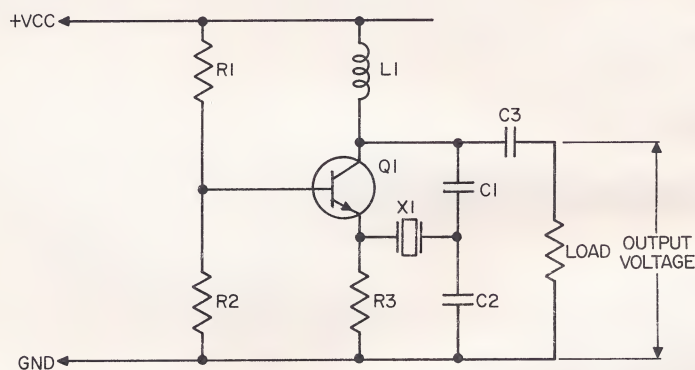


Medium Frequency Crystal Circuit

Specifications

Frequency Range	800KHz to 20MHz
Frequency Tolerance	$\pm 0.005\%$
Temperature Range	-40°C to $+70^{\circ}\text{C}$

This circuit is a modified Pierce type. Calculation of circuit elements can be obtained through use of established Pierce oscillator principles taking into account the finite input characteristics of a transistor. The output of this circuit is essentially a square wave with rise and fall times of 0.1 microsecond.



High Frequency Crystal Oscillator

Specifications

Frequency Range	15MHz to 100MHz
Frequency Tolerance	$\pm 0.005\%$
Temperature Range	-40°C to $+70^{\circ}\text{C}$

This circuit uses crystal units of both fundamental and overtone modes. It is an oscillator employing series resonance crystal units. The design objective involved equating the voltage gain of a common base transistor stage with tuned load and insuring that the voltage gain exceeds unity at the frequency of desired oscillation with a "worst case" crystal.

TUNING FORK OSCILLATORS

The art of tuning forks is very old, dating back to before the nineteenth century. Its use in early times was mostly academic. As time progressed tuning forks were used in calibration of musical instruments.

Work done by Eccles Jordan and others proved that frequency control using tuning forks as an electronic resonator was possible. From the early 1920's to the present, great strides in tuning fork oscillator design have resulted. With work done by Eisenhour, stabilities comparable to, and exceeding, crystal stabilities were made possible. Eisenhour's patents, covering temperature compensation by bimetallic means, increased stabilities to the order of 0.001% for a 70 degree change in temperature.

Today Eisenhour's ideas are still employed. Other means have been found, however, making use of constant modulus alloys which give comparable results.

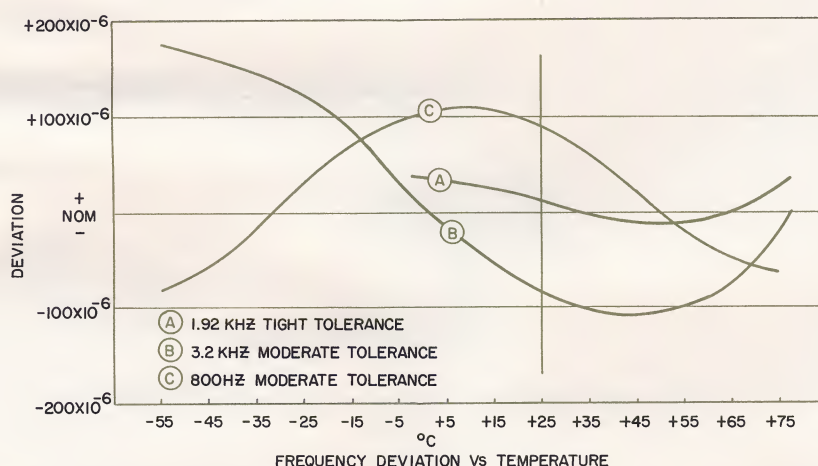
The frequency range for a basic tuning fork oscillator is restricted on the low frequency end by the size of the fork. It is possible, space permitting, to design a tuning fork oscillator to operate at the fundamental frequency of 60Hz. The practical range employed by most tuning fork oscillators manufacturers is from 400Hz to in excess of 10KHz. When operating the tuning fork in an overtone mode stable frequencies may be generated in excess of 75KHz.

Tuning fork oscillator temperature coefficients vary widely from manufacturer to manufacturer. The reason for this is that the variables involved in tuning fork design are many more than those found in the crystal resonators and each manufacturer handles individual variables differently.

The greatest variable encountered is that of materials. The interaction of temperature coefficients of the materials employed produce non-linear frequency deviations when subjected to temperature changes. Standardization of temperature coefficients of crystal oscillators, however, has been largely due to the predictable and reproductive qualities of quartz.

This is not to say, however, that tuning fork oscillators are not as good as comparable crystal oscillators since no trouble is incurred in achieving an overall frequency tolerance. It merely states that temperature coefficients of tuning fork oscillators are not as linear as crystal oscillators.

Typical frequency versus temperature curves for an Accutronics tuning fork oscillator is illustrated below.



Tuning fork oscillators when subjected to shock and vibration are virtually indestructible. They do exhibit, however, problems involving out-of-tolerance operations and frequency jitter. The vibration frequencies can approach 10% of the fundamental frequency for small amplitudes of vibration and the oscillator will remain within tolerance. It is more reliable however, for the oscillator manufacturer to use a fundamental frequency of two or more times the required output

frequency and then divide by means of a bistable device to the required frequency. For a typical 400Hz tuning fork oscillator a $\pm 0.05\%$ frequency deviation is noted when an interfering vibration frequency approaches within 10% of the fundamental frequency. As with crystal oscillators, the higher frequency fork oscillators show improved vibration and shock characteristics.

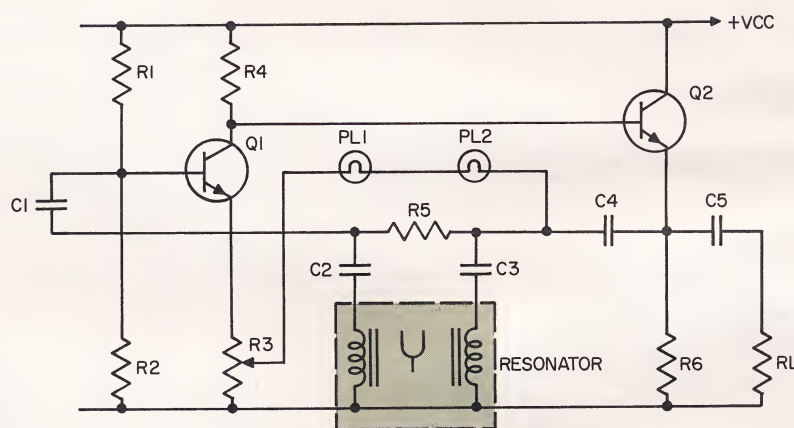
A characteristic not commonly known of tuning fork oscillators is that of a finite starting time. The starting time is proportional to the band width of the resonating element. Hence, since tuning fork oscillators have band widths of approximately .02Hz and corresponding circuit Q's of 5000, starting times for a typical 1KHz are in the range of two to five seconds. All crystal oscillators exhibit the same characteristics although the starting times are not as long since the band width is greater. Where necessary, starting times can be decreased by nearly an order of magnitude at the expense of a decrease in stability.

Another characteristic of importance for a tuning fork oscillator is that concerning orientation of the longitudinal axis of the fork tines. Gravity forces are not equal on both fork tines when the tines are in a horizontal position with respect to an imaginary horizontal plane assumed as the mounting surface. Most oscillator manufacturers tune the fork while the tines are in a vertical position. Differences in frequency, from nominal, range from 0.001% for high frequency forks to as great as 0.05% for lower frequency units as a result of orientation.

External magnetic fields may affect the frequency of a tuning fork oscillator if of sufficient strength. This is due to magnetic field changes occurring in the magnetic fork drive circuitry employed by most oscillator manufacturers. Where possible tuning fork oscillators should never be located close to strong magnetic origins. Some oscillator manufacturers employ piezo-electric or electro-static fork drive circuitry. Circuitry of this type is immune to permanent changes in frequency when subjected to magnetic fields.

Unlike crystal oscillators, tuning fork oscillators have no applicable military specifications, although semiconductor or other electrical components used in the fork assembly are covered. Prudence should be used when military specifications are to be met, since negligence in specifying military specifications where not actually required increases cost.

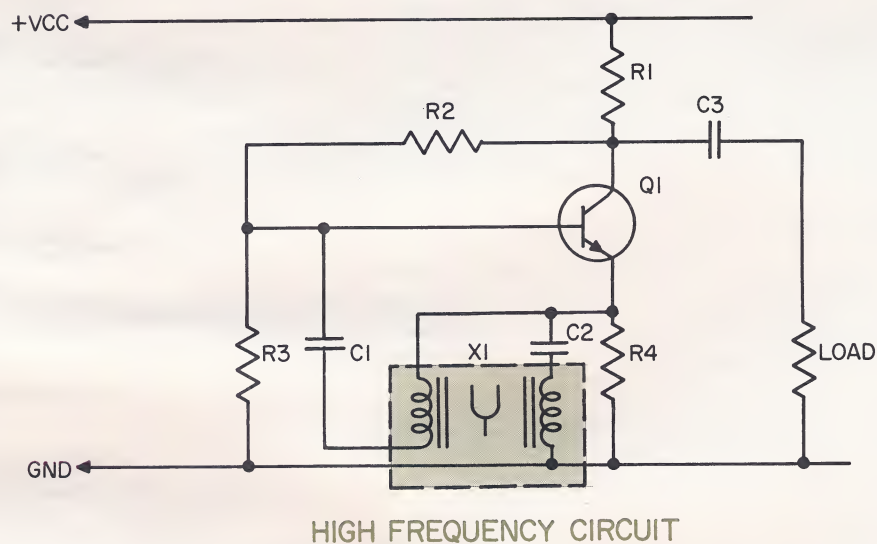
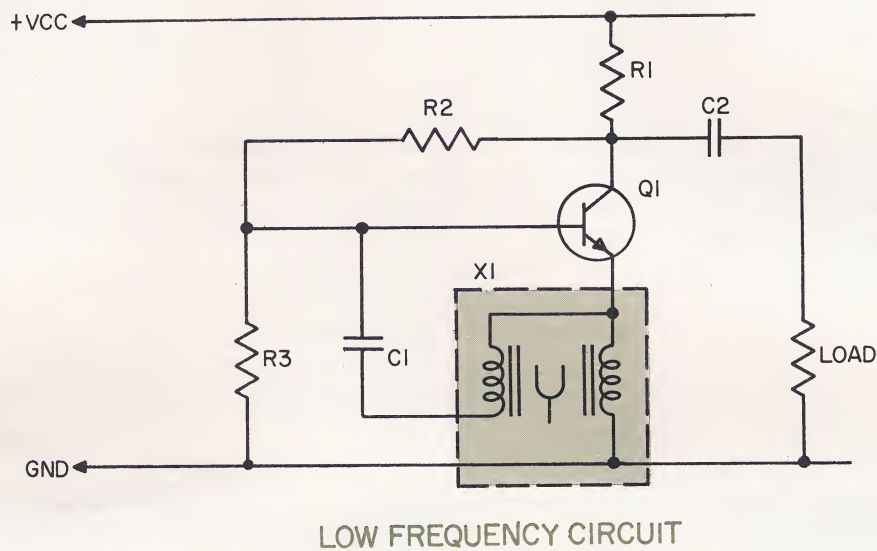
Typical Tuning Fork Oscillator Circuits



Tuning Fork Oscillator With Automatic Gain Control

When the need arises for a very precise low frequency generator most tuning fork oscillator manufacturers resort to some form of automatic gain control circuitry. The purpose of the AGC is to maintain constant, low level, signals to be applied to the fork drive assembly, thereby enhancing tight tolerance operation. Low level operation of the tuning fork is of paramount importance when drift rates are to be kept low. The circuit shown above demonstrates use of two special lamps (PL1 & PL2) to provide AGC action.

Typical Tuning Fork Oscillator Circuits



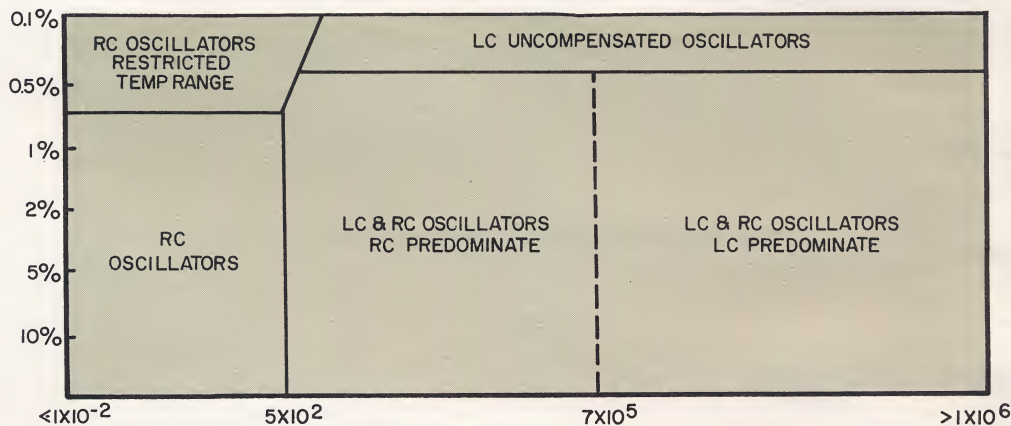
Tuning fork oscillators require the same conditions required by any other type of oscillator—greater than unity gain and 360° phase shift must exist simultaneously. The tuning fork oscillators shown above are analyzed as a modified form of a Hartley oscillator. The resonator $X1$ provides passive voltage gain and impedance transformation. At the desired resonate frequency attenuation through the network $X1$ is a minimum allowing sustained oscillations to ensue. The circuits are noteworthy since extremely good AC and DC stability is inherent.

LC AND RC OSCILLATORS

When a requirement arises for a relatively low cost oscillator application, the various forms of LC or RC oscillators are explored. With present day components tolerances in the order of $\pm 0.05\%$ to $\pm 5\%$ can be obtained over the frequency range of less than 1Hz to in excess of 500KHz. RC and some forms of LC oscillators have the unique advantage of withstanding large shock and vibration stresses. Such oscillators are capable of producing very low frequency sine wave outputs with low harmonic distortion content directly, thereby eliminating the use of higher frequency tuning fork or crystal oscillators and intermediate divider stages. Adaptations of RC and LC oscillators produce very desirable voltage controlled oscillators, or as more commonly called VCO's. A VCO produces linear change in frequency from some nominal center frequency as a result of a change in control voltage.

Frequency coefficients of both types exhibit varied shapes ranging from linear function for an LC oscillator employing Permalloy cores and Polystyrene capacitors to a doubly inflected curve when a typical RC oscillator is temperature compensated. A narrow operating temperature range makes oscillators of the type mentioned above especially attractive.

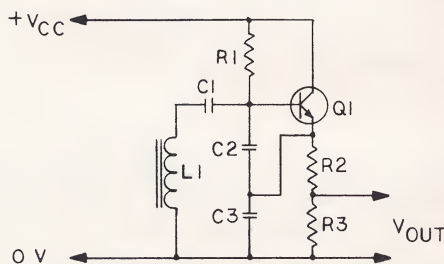
Figure 1 points out the various ranges where RC and LC oscillators are useful and economical.



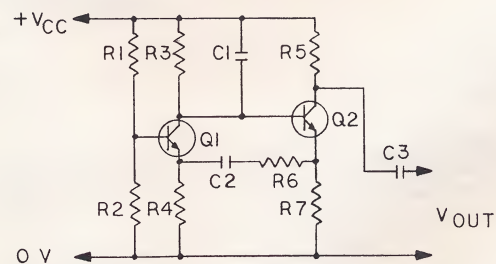
TYPICAL RC & LC OSCILLATOR USEAGE

Figure 1

The two schematics below illustrate the circuit configurations for both an LC and RC oscillator. The simplicity of either circuit make each extremely useful in those areas where specifications such as cost, size and relatively loose tolerance are of primary importance.



LC OSCILLATOR



RC OSCILLATOR

MISCELLANEOUS TYPES OF OSCILLATORS

There are many types of oscillators available from which the engineer may choose. The more common forms have been mentioned earlier and most engineers have, at least, a cursory knowledge of them. Some of the types to be discussed here include torsional and magnetostrictive oscillators. The stability of these types of oscillators depend upon stable mechanical properties of the basic material used in the frequency determining elements.

Magnetostrictive oscillators employ a magnetic field of varying intensity to change the physical dimensions of a metallic element. Metallic substances can be induced to vibrate in a number of possible ways. Some of the more common modes of vibration are length, thickness and radial deformation. Figure 1 illustrates a typical oscillator circuit employing a magnetostrictive frequency determining element. Magnetostrictive oscillators are useful in the frequency range of 20KHz to 500KHz. They are capable of stabilities similar to those obtained with tuning fork oscillators.

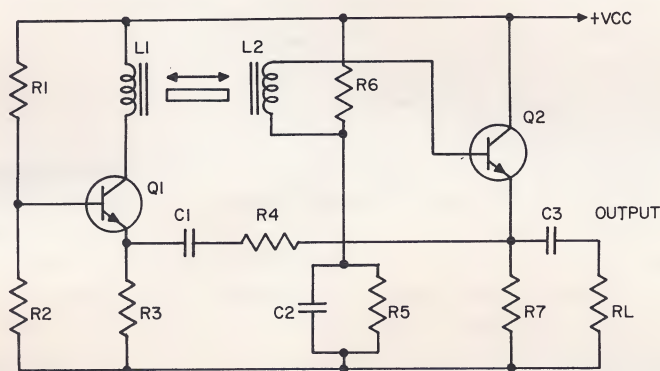


Figure 1

Torsional oscillators produce sustained stable frequencies as a result of a twisting movement imparted to some structure. An example of a torsional oscillator is shown in Figure 2. In this case a circular mass is suspended by and securely fastened to a wire beam. The wire beam is connected to a mounting base.

Magnetic drive is obtained through use of permanent magnet biased drive coils acting upon magnetic pole pieces located in the suspended mass.

When the system is connected properly to an amplifier circuit, induced voltage creates a changing magnetic force. A torsional or twisting movement in the wire beam is thereby produced. The frequency of the resulting oscillation is determined by the amount of mass suspended and the characteristics of the wire beam support.

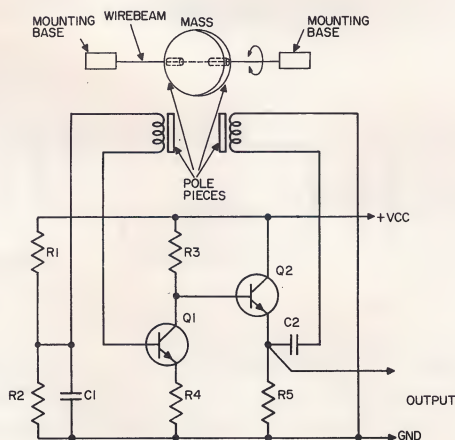


Figure 2

INTEGRATED CIRCUIT OSCILLATORS

The electronic industry has for the past several years, witnessed the successful influx of integrated circuitry to both the digital and analog fields. At present more and more electronic firms producing widely diversified products are finding uses for the many forms of logic and small signal functions provided by integrated circuitry.

Few oscillator manufacturers are, at this time, producing oscillators that are truly compatible with integrated circuitry. Most oscillator manufacturers rely on their customers to modify the outputs of their units for integrated applications.

Many benefits are derived from usage of I.C. Of these the most significant is the reduction of volume required to perform a function. The oscillator manufacturer can utilize this benefit at once. With it he now has the capability to furnish oscillators providing frequencies lower than ever before in cubic measure never thought possible.

All is not bliss, however, the low levels required by today's IC demand more design skill and ingenuity from the oscillator manufacturer. Basic oscillator design for I.C. applications require the oscillator to operate with supply voltages as low as three to four volts.

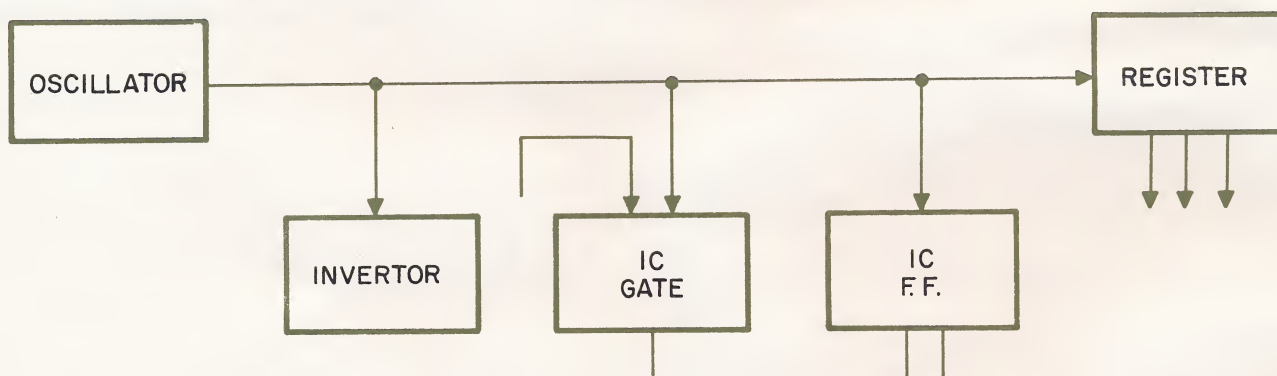
Accutronics currently has several standard lines of I.C. application intended oscillators, both tuning fork and crystal, and is pursuing development in specialized I.C. areas also.

When specifying oscillators for I.C. applications, several points are to be kept in mind. The most important, however, concerns the output voltage specification. Since most systems engineers do not know that I.C. compatible oscillators are available, it has been and still is, standard practice, for example, to specify a 26 volt supply voltage for the oscillator and take for an output voltage whatever the oscillator manufacturer supplies. This can lead to problems since some I.C., particularly digital types, can be damaged and sometimes destroyed by inadvertent application of high input voltage from a low source impedance. Even if high input voltage does not cause destruction, incorrect and misleading operation may result which can result in very costly trouble shooting.

Whenever possible the oscillator manufacturer should be made aware that the oscillator a customer has ordered will be used in an I.C. application. He should be provided with information regarding the manufacturer of the I.C., the type of circuit he will be driving and the voltage level at which it will operate.

It may take an additional buffer stage to meet the output current demanded and unless the load is specifically detailed sufficient output may not be available. This is especially important in complex logic systems where it is possible to have a large number of integrated circuits connected to the system clock. In cases such as this a list should be prepared identifying the individual type and quantities of IC comprising the load on the oscillator.

An example of a typical integrated circuit application is illustrated below:



It should be noted that the above circuit could easily be driven by insertion of a buffer stage between the oscillator and the load circuitry. It is, in most cases, possible for the oscillator manufacturer to enclose the buffer stage in the oscillator package at nominal cost with a resulting savings in system board space.

OUTPUT AND SYSTEM INTERFACE CIRCUITRY

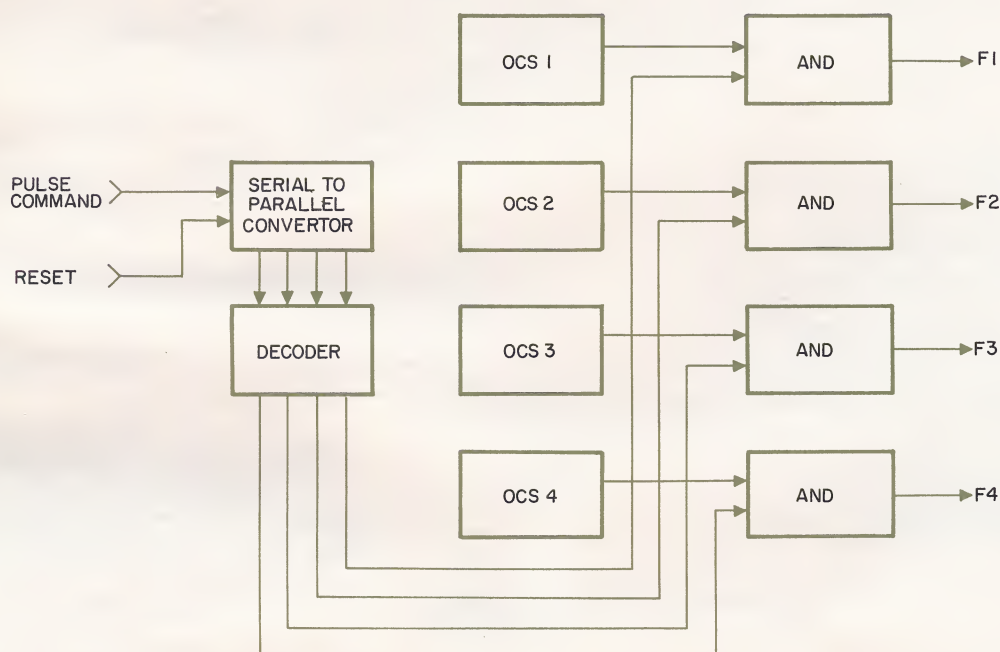
The system and instrument engineer should be aware of the versatility of the oscillator manufacturer. The oscillator manufacturer can greatly simplify the system designer's function by providing special output circuitry, multiple frequencies from one oscillator and, where necessary, he can supply high voltage and high power. It is within his means to supply high amplitude stability output stages capable of driving LVDT's and other precision measuring instruments requiring tight tolerance amplitude stability. When an application arises for a system clock, the oscillator manufacturer can supply a tight tolerance oscillator with integral equipment preset dividers capable of dividing the oscillator by discrete numbers, thereby producing a systems clock with multiple outputs.

Applications have arisen where a number of non-harmonically related frequencies have been required. The oscillator manufacturer can supply all frequencies in one assembly having provision to digitally produce one of the required frequencies when the proper binary information is supplied as a common input. Applications constantly arise requiring frequency generators having rise and fall times of the output waveform of less than 50 nanoseconds to less than 1 nanosecond. The oscillator manufacturer is capable of meeting this specification also. When a requirement calls for a special pulse waveform, the oscillator manufacturer can, in most cases, provide the desired waveform as an integral part of the oscillator.

By means of the examples mentioned previously and through information to be gained from the application sketches following, it is hoped that sufficient knowledge will be imparted to those electronic engineers whose job is to provide a simple solution to a problem. It is hoped that if nothing else, an intimate insight into the oscillator manufacturers function will be obtained.

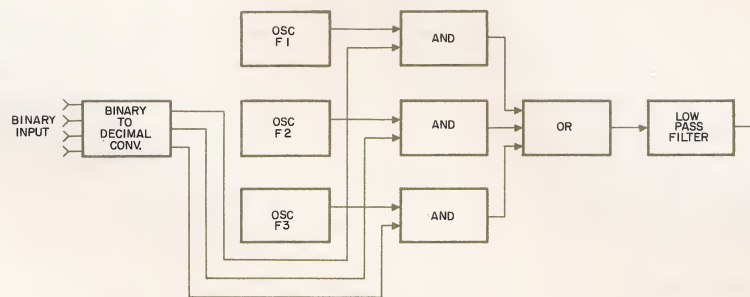
Following are a few of the many special systems Accutronics has delivered.

Remote Selection of Timing Frequencies by Pulse Number Input



A major aero-space company required a series of oscillators for use in the LEM program. In discussing the requirements with the project engineer Accutronics proposed to supply the entire timing system. The system was to deliver timing information upon command of a sequence of pulses received would correspond to that timing period desired.

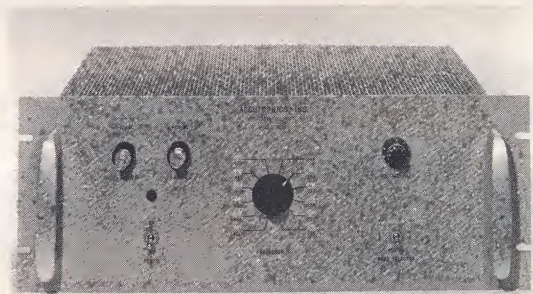
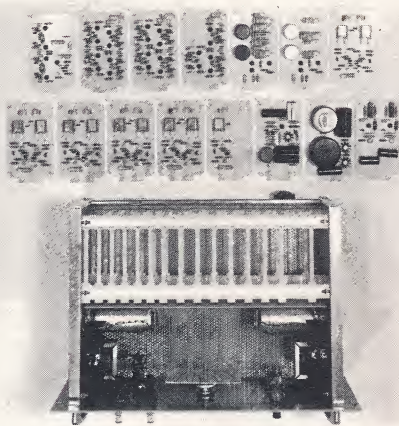
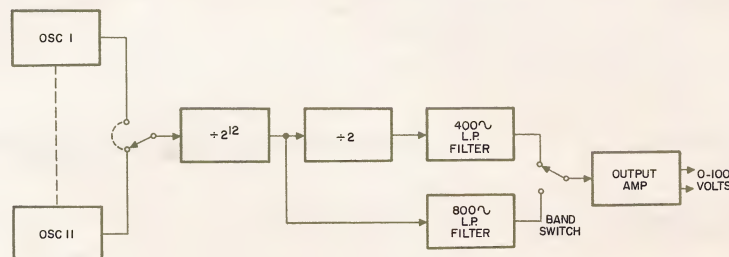
I.R.I.G. TEST MODULE



Knowledge of the customers requirements provided the test module shown above. It was required to provide center and band edge signals for several I.R.I.G. channels. A further requirement was that the accurate signals demanded were to be delivered upon receipt of a binary command.

It was found again that the system as shown was more economical to the customer than if he purchased the oscillator alone and designed and manufactured the module himself.

Precision Frequency and Voltage Generator



Specifications

- 11 frequencies in each of 2 bands
- Tolerance $\pm 0.0005\%$
- Output Voltage 0-100V rms adjustable

Accutronics was able to provide the frequency generator shown above at a considerable saving in cost to the customer. Knowledge of the good tolerance available from certain cuts of the AT cut crystal provided the required frequency tolerances without use of oven power.

TYPICAL OSCILLATOR SPECIFICATIONS

Illustrations in the preceding sections review the many forms of special circuitry required to produce output levels and characteristics which are classified as non-standard. The characteristics depicted therein are not usually available in off the shelf oscillators.

It is useful and economical to know what standard specifications are. Wise procurement necessitates general knowledge as to what the oscillator manufacturer can provide without excessive in-house engineering. It is intended that the following information will provide a general background in this area.

Since an infinite number of combinations exist involving frequency, frequency tolerance and temperature range, some means of compressing this information into a useful form should be available. Figure 1 below attempts to illustrate this data compression technique by showing at a glance combinations of frequency, frequency tolerance and temperature range. The shaded areas indicate that some difficulty is involved in meeting that tolerance in the temperature range shown. It should be noted that only four temperature ranges are indicated. This does not mean that they are the only ranges available. It merely indicates that the ranges shown are standard and are based on customer preference for these ranges. Other tolerances and specifications are available when required.

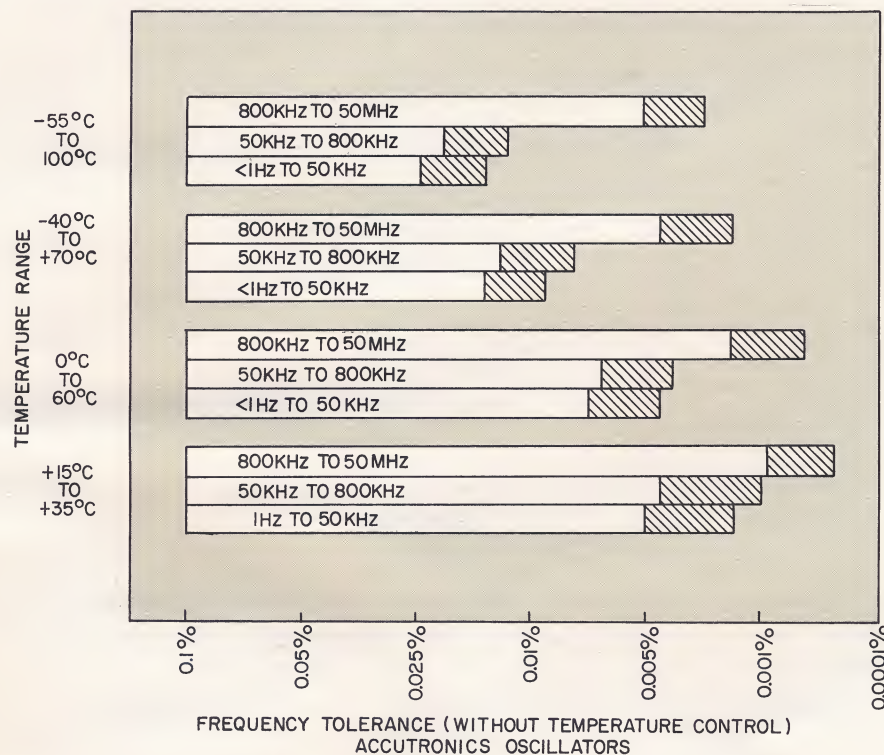


Figure 1

Many questions arise concerning the relationship between output and supply voltage. Figures 2 & 3 illustrate this relationship for both sine and square oscillators. It should be noted that three curves exist in Figure 2. This merely indicates that output voltage is a function of frequency as well as supply voltage. The voltages shown are those obtained typically in standard

units and can be easily changed when required. The lower curve in Figure 3 shows the design value of output voltage produced by the oscillator. It is possible with slight modifications, to produce an output voltage up to 90% of the supply voltage.

For both sine and square wave units a load resistance of $10K\Omega$ is implied as a standard load.

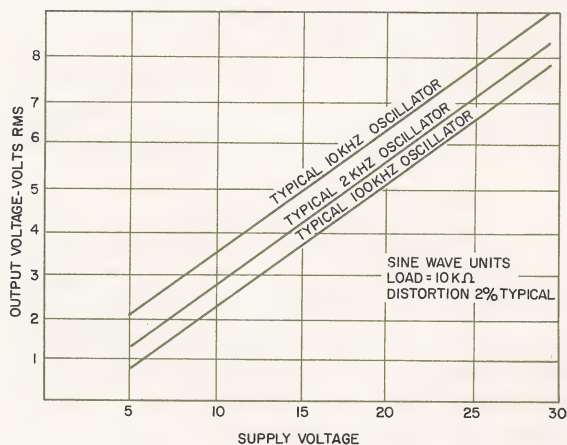


Figure 2

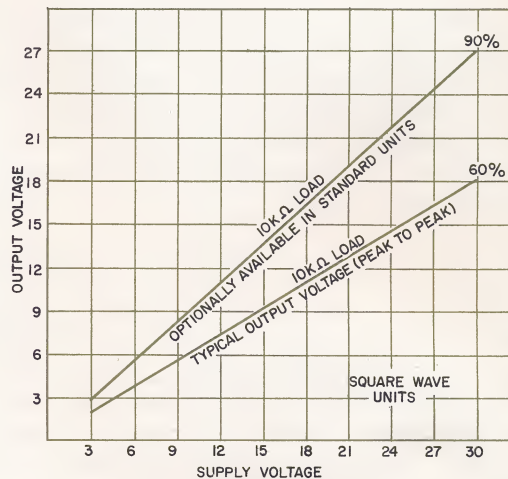


Figure 3

Figure 4 illustrates the amount of current required for both sine and square wave units with supply voltage as a variable. Other specifications which will influence the value shown are rise time, distortion, and frequency stability as well as load resistance.

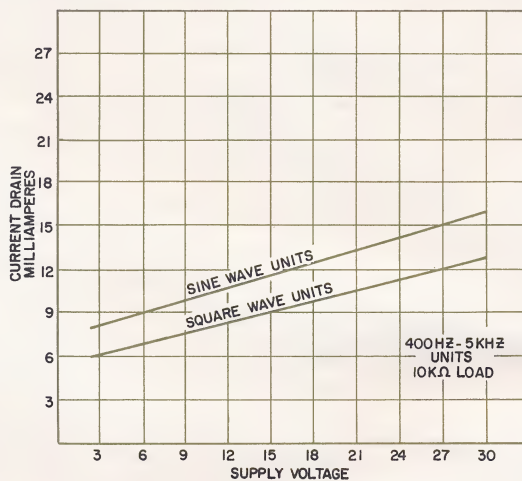


Figure 4

The chart below summarizes rise time characteristics for a standard line of square wave oscillators. It should be noted that the rise time shown in Table 1 are typical and can be decreased if necessary.

FREQUENCY	SPECIFIED T_r	TYPICAL T_r
<1Hz to <400Hz	<5 μ sec.	<2 μ sec.
400Hz to <1KHz	<5 μ sec.	<3 μ sec.
1KHz to <10KHz	<5 μ sec.	<1 μ sec.
10KHz to <500KHz	<1 μ sec.	<0.5 μ sec.
500KHz to <1MHz	<0.2 μ sec.	<0.1 μ sec.
1MHz to 10MHz	<100 ns - 30 ns	<500 ns - 20 ns
10MHz to 100MHz	<30ns - <3ns	<20ns - <2ns

Table 1

TYPICAL STANDARD OSCILLATORS

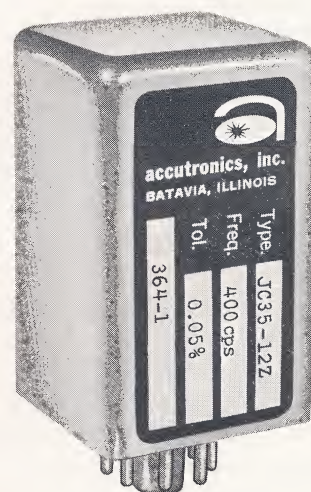
JC Low Cost Series

FREQUENCY: 50 cps to 50 mc as specified
FREQUENCY TOLERANCE: $\pm 0.05\%$ or better over temperature range
FREQUENCY ACCURACY: $\pm 0.025\%$ or better at 25°C
TEMPERATURE RANGE: 0°C to 60°C
OUTPUT POWER: >15V p/p square wave with <5 μ sec rise time
>3V rms sine wave with <5% total harmonic distortion

NOTE: The above outputs are typical with a 26 volt dc input and 10K load.

VOLTAGE SUPPLY: 3v to 30v dc as specified

DIMENSIONS: 1-1/2 x 1-1/2 to 4-1/2" tall depending on frequency



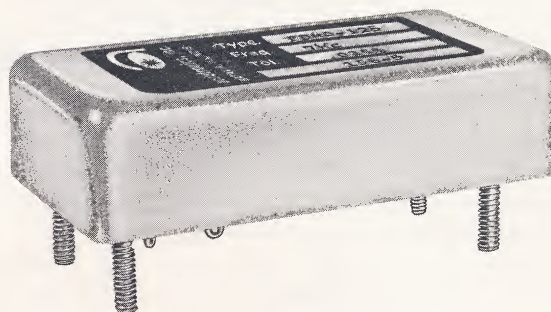
FD40 Flat Package Series

FREQUENCY: 400 cps to 50 mc as specified
FREQUENCY TOLERANCE: $\pm 0.025\%$ or better over temperature range
FREQUENCY ACCURACY: $\pm 0.01\%$ at 25°C
TEMPERATURE RANGE: -25°C to +75°C
OUTPUT POWER: >15V p/p square wave with <5 μ sec rise time
>3V rms sine wave with <5% total harmonic distortion

NOTE: The above outputs are typical with a 26v dc input and 10K load.

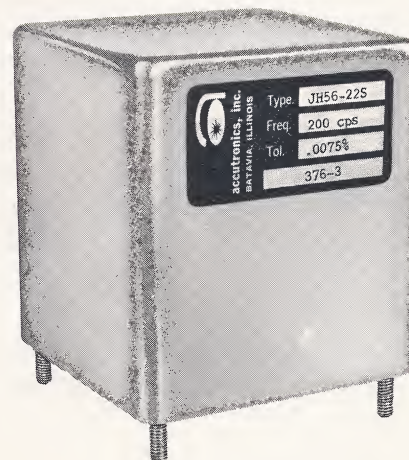
VOLTAGE SUPPLY: 3v to 30v dc as specified

DIMENSIONS: 1-1/2 x 3-1/2 to 1" tall depending on frequency



JH Power Series

FREQUENCY: 50 cps to 7 kc as specified
FREQUENCY TOLERANCE: $\pm 0.0075\%$ or better over temperature range
FREQUENCY ACCURACY: $\pm 0.005\%$ at 25°C
TEMPERATURE RANGE: 0°C to +60°C
OUTPUT POWER: up to 1 watt. sine or square wave
VOLTAGE SUPPLY: 12v to 30v dc as specified
DIMENSIONS: 3-1/16 x 3-1/16 x 3 to 4-11/32" high depending on frequency



JJ Medium Temperature Range Series

FREQUENCY: 50 cps to 50 mc as specified

FREQUENCY TOLERANCE: $\pm 0.005\%$ or better over temperature range

FREQUENCY ACCURACY: $\pm .002\%$ or better at 25° C

TEMPERATURE RANGE: 0°C to +60°C

OUTPUT POWER: > 15V p/p square wave with < 5 μ sec rise time
> 3V rms sine wave with < 5% total harmonic distortion

NOTE: The above outputs are typical with a 26V dc input and 10K load.

VOLTAGE SUPPLY: 3v to 30v dc as specified

DIMENSIONS: 50 cps to 400 cps — 1-3/4 x 1-3/4 to 4-1/4" tall
400 cps to 10 — 1-1/2 x 1-1/2 to 4-1/4" tall

Note: Oscillator height depends on frequency



AC Wide Temperature Range Series

FREQUENCY: < 50 cps to 50 mc as specified

FREQUENCY TOLERANCE: $\pm 0.025\%$ or better over temperature range

FREQUENCY ACCURACY: $\pm 0.003\%$ or better at 25°C

TEMPERATURE RANGE: -55°C to +125°C

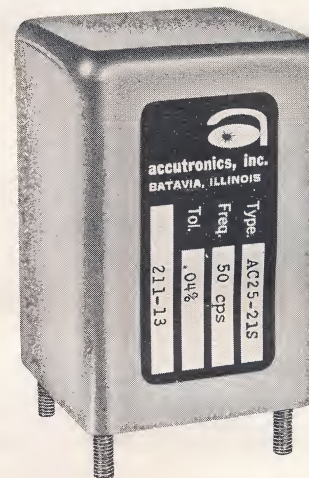
OUTPUT POWER: > 15V p/p square wave with < 10 μ sec rise time
> 3V rms sine wave with < 10% total harmonic distortion

NOTE: The above outputs are typical with a 26v dc input and 10K load.

VOLTAGE SUPPLY: 3v to 30v dc as specified

DIMENSIONS: 50 cps to 400 cps — 1-3/4 x 1-3/4 to 4-1/4" tall
400 cps to 10 mc — 1-1/2 x 1-1/2 to 4-1/4" tall

NOTE: Oscillator height depends on frequency



FD20 115 V AC Supply Series

FREQUENCY: 400 cps to 50 mc as specified

FREQUENCY TOLERANCE: $\pm 0.025\%$ or better over temperature range

FREQUENCY ACCURACY: $\pm 0.003\%$ or better at 25°C

TEMPERATURE RANGE: -25°C to +75°C

OUTPUT POWER: > 15V p/p square wave with < 5 μ sec rise time
> 4V rms sine wave with < 5% total harmonic distortion

NOTE: The above outputs are typical with a 10K load.

INPUT VOLTAGE: 110V to 117V ac, 50 to 60 cps

DIMENSIONS: 2 x 2 x 3 to 5-3/8" tall depending on frequency



MN High Stability Series

FREQUENCY: 100KHz to 10MHz

FREQUENCY TOLERANCE: $\pm 0.0001\%$

OPERATING TEMPERATURE: -30°C to $+60^{\circ}\text{C}$

SUPPLY VOLTAGE: 12 to 30 volts

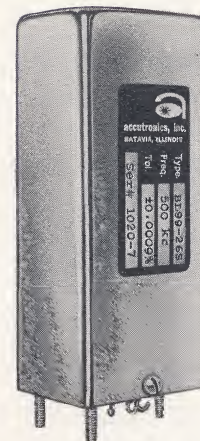
OUTPUT VOLTAGE: 10 to 50% of supply voltage

LOAD IMPEDANCE: 50Ω to $10\text{K}\Omega$

OVEN SUPPLY: 28V dc to 115V ac

RISE TIME: .1 $\mu\text{sec.}$ to 20 ns

SIZE: 1-1/2 x 2 x 4-5/8"



JM High Accuracy Series

FREQUENCY: 400 cps to 50 kc as specified

FREQUENCY TOLERANCE: $\pm 0.0005\%$ or better over temperature range

TEMPERATURE RANGE: 0°C to 60°C

OUTPUT POWER: >15V p/p square wave with <5 μsec rise time
>3V rms sine wave with <5% total harmonic distortion

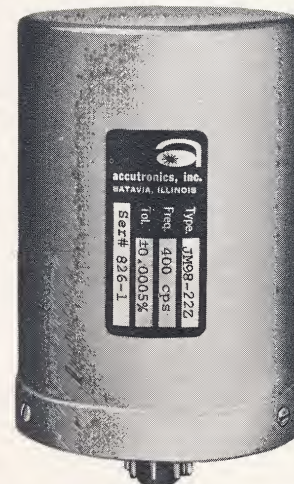
NOTE: The above outputs are typical with a 26 volt dc input and 10K load.

VOLTAGE SUPPLY: 12v to 30v dc as specified

OVEN SUPPLY: 6v dc to 30v dc 6v ac to 115v ac

DIMENSIONS: 3-1/4" Dia. x 4-3/4" High

Note: The JM series incorporates a special trimming device to allow precise setting of the frequency to WWV.



YOUR SERIES Designed To Your Requirements

FREQUENCY: <1 cps to 50 mc as specified

Multiple frequency output as specified

FREQUENCY TOLERANCE: $\pm 0.0009\%$ to $\pm 0.5\%$ over temperature range

FREQUENCY ACCURACY: $\pm 0.0005\%$ to $\pm 0.5\%$ at 25°C

TEMPERATURE RANGE: -75°C to $+125^{\circ}\text{C}$

OUTPUT POWER: Up to 50 watts as specified

WAVEFORMS: Sine with <0.5% distortion

Square with <50 nanosec. rise and fall time

Pulse, ramp, sawtooth, etc.

VOLTAGE SUPPLY: 3 volts to 36 volts dc and 12 volts to 220 volts ac

DIMENSIONS: 1-1/2 x 1-1/2 x 1" to 8 x 12 x 8"

TERMINATION: Octal, solder pin type, P.C. type, etc.

MOUNTING: Studs, threaded inserts, etc.



If your requirement falls within the above parameters, we can be of assistance to you. In the past year we have designed over 300 non-standard type oscillators. Let our engineering staff assist you with your problem.

OSCILLATOR PACKAGING

Oscillators, like people, come in all shapes and size. All oscillator manufacturers illustrate in their catalogs a line of "standard" units. These "standard" units indicate capability and are representative of the manufacturers ability. It is an accepted fact that most oscillators that are purchased today are designed to the customers requirement. Let's explore the basic package configuration.

SHAPE FACTORS

Figure 1 illustrates four basic package configurations. The flat package is ideal for mounting to P.C. boards and uses a minimum of space. The square "relay can" type configuration, with an octal plug, is a very popular package because of the ease of replacement and interchangeability. For shock and vibration and permanent mounting the "bolt down" configuration provides the greatest protection, coupled with a solder pin type header and hermetically sealed this type of package is ideal for military applications. In addition to the "can type" package, Accutronics also packages oscillators in a "card" configuration as illustrated. The P.C. board contains two oscillators in addition to a frequency trimming device which allows precise setting of the oscillators to the exact frequency. This package allows the system design engineer to purchase a complete "block" for his system from one source.

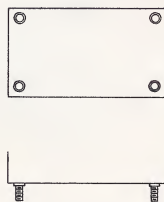
All oscillator manufacturers are versatile and can provide you with a multitude of shapes and size. Keep in mind, however, that it is only possible to put 3 cubic inches of oscillator into a 3 cubic inch package. Oscillator manufacturers are continually looking for new and better methods of packaging and the introduction of I.C.'s has opened a new area of size reduction possibilities.

Figure 1

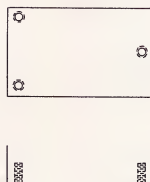


MOUNTING CONFIGURATION

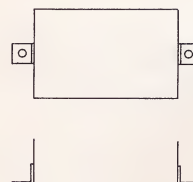
Now that you have decided on a form factor the next logical step is to attach this package to your equipment. The three methods illustrated below are the most popular.



Type A



Type B



Type C

STUDS

Threaded studs, type A, can be provided in four sizes; #4-40, #6-32, #8-32 and #10-32. The size selected is dependent on weight and form factor of the package. Your oscillator manufacturer can recommend the optimum size based on this experience. Many times only one or two studs are required. The type A configuration is normally used when mounting to a chassis or P.C. board. At the top of the threaded stud is a 1/32" shoulder which allows the oscillator to "stand off" the mounting surface. (This is especially advantageous when you have a heat conduction problem with your chassis and you wish to keep it away from the oscillator.)

THREADED INSERTS

The type B mounting configuration is most popular for P.C. board applications. Available in a #4-40 or #6-32 size this method eliminates the stud and nut from protruding from the back of the P.C. board. The threaded insert used with a binding head screw presents a minimum silhouette.

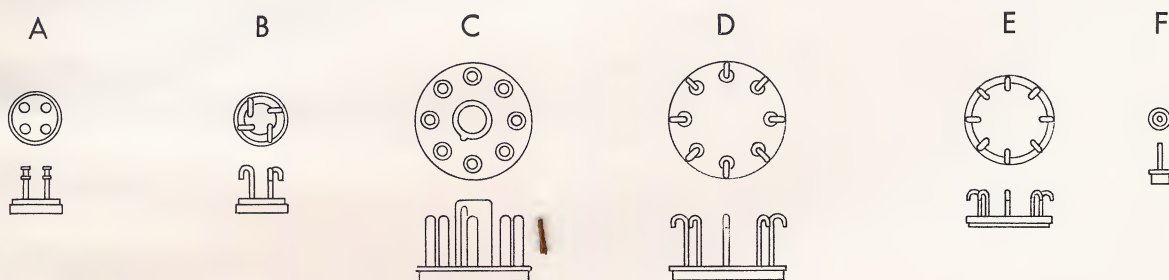
FLANGE MOUNT

The flange or bracket mount is available in many different variations and can be tailored to your particular application. The bracket can be welded to any surface to allow mounting of the oscillator in any position on your chassis.

HEADERS

There is a wide range of headers available to be used on the oscillator package. Illustrated are the more popular types. Type A is commonly used in "wire wrap" soldering applications while Type B "hook type" leads itself to quick hand soldering techniques. The Type C header is the standard RETMA octal header widely used by the industry.

The Type D and E are the same except for size variation. Where multiple pins are required for several outputs, voltages or tie points the above types are recommended. The Type F is used for P.C. board applications and are spaced in .100" grid pattern to conform with accepted P.C. board layout standards. The number of pins is of course dependent on the requirement but the oscillator manufacturer can place the pins in the most advantageous position to help your board layout.



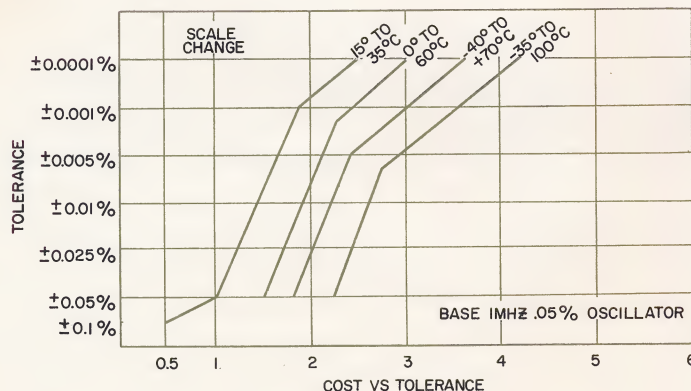
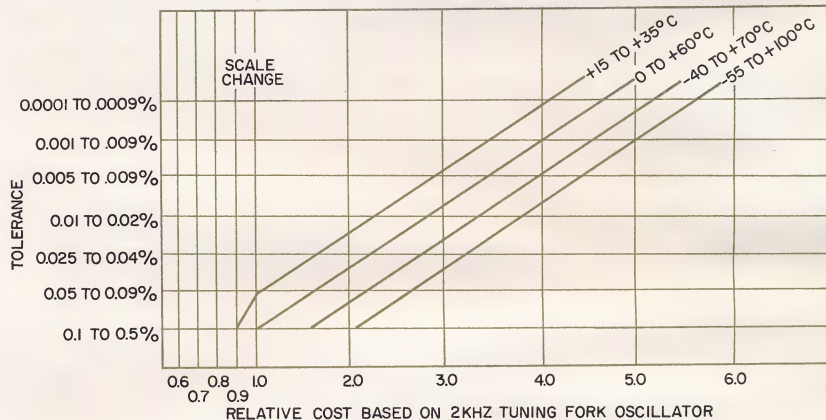
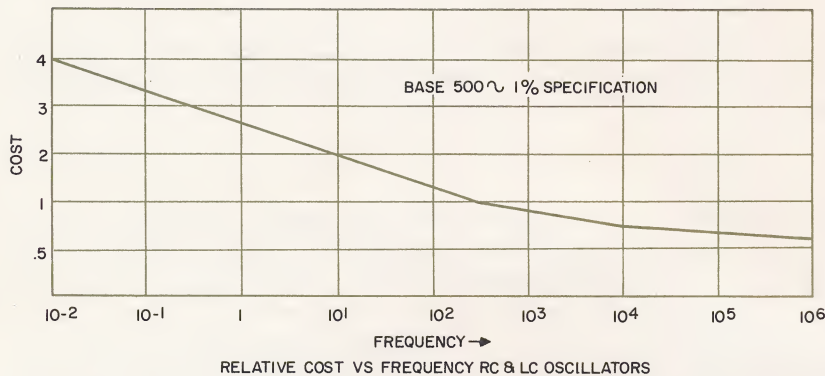
CONCLUSION

This chapter could cover many additional package configurations but we feel that the foregoing provides you with sufficient information to cover the majority of applications. If you have a requirement that has not been covered, please contact the Engineering Service Department for additional information.

OSCILLATOR PRICING

What does an oscillator cost? This question can only be answered in one way...it depends on the specifications. In general the most critical specification affecting cost is the frequency tolerance. As you can see from the graph the cost increases as the frequency tolerance improves. The cost of a 2KHz oscillator with a temperature range of 0°C to 60°C and a frequency tolerance of $\pm 0.009\%$ is about five times the cost of an oscillator with a tolerance of $\pm 0.05\%$ over the same temperature range. From this illustration you can witness the results of "over specifying" or building in "cushions". This practice is costly and should be avoided whenever possible. The graphs are not intended to be exact but to give the reader a rule of thumb in estimating the effect of frequency tolerance specification on the overall cost of an oscillator.

To keep the cost of your oscillator at a minimum, choose a unit from the manufacturers "standard" line or use the "standard" unit as a base point and add the necessary modifications to meet your requirements. The use of the "OSCILLATOR SPECIFICATION QUESTIONNAIRE" covered in Section 10 should be of significant help in pinpointing your exact requirements.



OSCILLATOR SPECIFICATION QUESTIONNAIRE

As the systems of today become more complex and sophisticated it is axiomatic that the individual components making up these systems will also require a higher order of sophistication.

No longer can the design engineer specify only frequency, voltage, waveform and tolerance and expect to receive an oscillator which will perform satisfactorily in his system. Misunderstandings and delays will almost certainly result because of the lack of sufficient information and more important the possibility of receiving a device that will not completely perform in the system.

For the past several years Accutronics, Inc. has made an intensive study of the parameters involved in oscillator specifying. The oscillator specifying form illustrated in Figure 1 represents the most pertinent information required to "worst case" design an oscillator to meet the high degree of quality and reliability demanded by today's sophisticated equipment. Although some of the requested information may seem ambiguous at first glance, it will become apparent after reading this chapter, that all of this information is vital to good oscillator design. It is of extreme importance to the oscillator manufacturer that he has a "total oscillator requirement concept" in order to design a device which will meet the design engineers need.

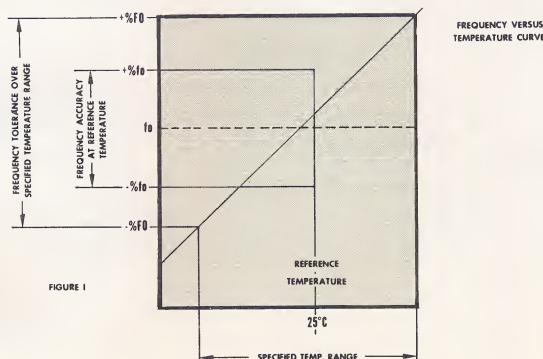
The greatest problem that an engineer has in specifying an oscillator is the determination of all the parameters involved. The illustrated specification questionnaire should be of significant value to the design engineer on future applications. This questionnaire will help eliminate the costly mistakes of over specifying or the ordering of standard units which may be more costly than the requirement demands. Since most standard oscillators are custom made to a specific set of requirements, it normally does not cost any more to procure exactly what is needed, and in a number of cases can be less costly than a standard unit.

The various oscillator parameters and their importance to the overall design is covered in complete detail in this article. Oscillators in the range of $<1\text{Kz}$ to 100HMz are completely defined when using the questionnaire and can be of significant help in preliminary system design.

Particular attention should be given to the following parameters when specifying an oscillator:

FREQUENCY: Specify the exact frequency. Oscillators are available at any specified frequency in either whole number frequencies or fractional frequencies. Oscillators having more than one output frequency are also available. Frequency generators having multiple output frequencies bearing integral relationships to each other are especially economical.

FREQUENCY ACCURACY AND TOLERANCE: The maximum amount an oscillator may deviate from a nominal center frequency at a specified temperature is defined by frequency accuracy. Frequency accuracy is expressed in $\pm$ parts per million (PPM) difference or $\pm$ percentage difference from a nominal center frequency. Frequency accuracy is usually specified at 25°C but can be specified at any other temperature. The maximum amount an oscillator may deviate from a nominal center frequency when subjected to environmental stresses, shock and voltage variances is defined by frequency tolerance. Frequency tolerance is usually a critical specification in most applications. Caution and prudence must be used when specifying frequency tolerance since oscillator cost and delivery are definitely related to this specification. Do not over specify. The relationship between frequency accuracy and frequency tolerance is illustrated graphically in Figure 1.



FREQUENCY DRIFT: If the frequency drift over a period of time is critical this parameter be specified, i.e. 5 ppm for 10 min. or possibly .01% per week.

ENVIRONMENTAL SPECIFICATIONS

TEMPERATURE RANGE: Two temperature ranges appear on the specification sheet. One defines the normal operating temperature range to which all other operating specifications are based. The other range is the non-operating or storage environment to which the oscillator can be subjected. It is important that both temperature ranges be specified since improper and out of tolerance operation may result if the oscillator is thermally "shocked" by being placed in an environment not specified.

ALLOWABLE STARTING TIME: Low frequency oscillators have a tendency to reach full amplitude at a much slower rate than high frequency oscillators. A 400Hz oscillator can take as long as 5 seconds to reach full amplitude but where specified can reach full amplitude in 70 msec. This specification should be carefully evaluated and specified to avoid problems with the circuitry following the oscillator. A total system timing review should be made to insure adequate start up time for the oscillator. In some applications the oscillator is "free running" and is keyed in and out as needed.

OVEN PERMISSABLE: In the event of extreme temperature environments and tight frequency tolerance, it is sometimes necessary to place the oscillator in an oven. The oven will require a nominal warmup time of 15 to 20 minutes, causing the frequency of the oscillator within to change until the oven has stabilized.

SHOCK AND VIBRATION: Shock and vibration will have a definite effect on the oscillator performance and will show up as jitter or frequency modulation. Jitter and frequency modulation problems are of particular importance at the lower frequencies <1Hz to 100KHz. These effects should be taken into consideration in the early design stages. The design of the oscillator can be modified to prevent serious malfunction or damage. If the shock or vibration is only in one plane it should be called out in order to allow orientation of the crystal or tuning fork in the best position to minimize the effects of the shock or vibration.

MILITARY SPECIFICATIONS: There are no military specifications covering the complete oscillator assembly. There are, however, mil specs covering crystal and other discrete components used in an oscillator. If your oscillator is to be used in a military system, you should specify the applicable mil spec and class which covers the entire system, i.e. Mil-E-16400 Class II. If all the components used in the oscillator are to be mil approved devices, it should be specified since the use of mil approved components will increase the cost of the oscillator substantially.

POWER SUPPLY SPECIFICATIONS: When supplying information regarding the power supply used to operate the oscillator, provide as much detailed data as possible. In most loose frequency tolerance oscillators and those with non-critical specifications supply voltage, tolerance and maximum current drain are the only specifications required by the oscillator manufacturer. However, there are cases where the frequency tolerance or output specification dictate a complete knowledge of the power supply. Typical troubles which may arise when complete information is not given are as follows: frequency modulation and jitter caused by ripple on the power supply; increased distortion in the output waveform due to a ripple component; transients which will cause sizeable changes in all characteristics and possible destruction of semiconductor devices in the oscillator; poor output amplitude stability due to a short or long term change in supply voltage. Always specify the polarity of the power supply as the choice between internal use of NPN or PNP transistors is usually dictated by this specification. An example where this is important is when the oscillator is used to drive a transistor inverter stage or flip-flop and the "0" level or low level should come from a low impedance source. If there is any doubt whether to include a specification or not, include it and leave the design of the oscillator and the importance of this speci-

COMPANY_____	YOUR NAME_____
ADDRESS_____	TITLE_____
CITY & STATE_____	DEPT._____
TELEPHONE_____	EXT._____

FREQUENCY SPECIFICATIONS

Frequency:_____

Frequency Accuracy: $\pm$ _____ @ _____ °C

Frequency Tolerance:_____

Drift:_____ % per _____

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature Range:_____ °C to _____ °C

Storage Temperature Range:_____ °C to _____ °C

Allowable Starting Time:_____ seconds

Is an oven permissible: ☐ Yes ☐ No

Warmup Time:_____ min. @ _____ °C

Oven Supply:_____ volts _____ max. amperes

Shock (operating):_____ (non-operating):_____

Vibration (operating):_____ (non-operating):_____

Military Specifications:_____

POWER SUPPLY SPECIFICATIONS

Supply Voltage:_____ Tolerance: $\pm$ _____

Max. Current Drain:_____ amps

SUPPLY RIPPLE

% of supply voltage:_____ volts pk. to pk.

Frequency of ripple:_____ cycles/sec.

SUPPLY POLARITY

Positive: ☐

Negative: ☐

TRANSIENTS

Peak Voltage:_____

Duration:_____ μ sec.

Repetition:_____

TYPE OF SUPPLY

Battery: ☐

AC Line: ☐

Electronic Supply: ☐

OUTPUT SPECIFICATIONS

Output Waveform ☐ Sine ☐ Square ☐ Other (enclose sketch)

Distortion Total Harm:_____ % Max.

Rise Time:_____ μ sec.

2nd Harmonic:_____ % Max.

Fall Time:_____ μ sec.

3rd Harmonic:_____ % Max.

Symmetry:_____

Output Voltage:_____ volts rms

Output Voltage:_____ volts p/p

Is a DC component in the output permissible: ☐ Yes ☐ No

fication to the discretion of the oscillator manufacturer as only he knows how this specification will influence the performance of the unit.

OUTPUT SPECIFICATION: More troubles arise in the specifying of oscillator output characteristics than any other associated specification. It is here that there is an infinite number of possible combinations that you may desire. Specifying whether the output is to be sine wave or a square wave is only the beginning, even in "standard" units. There is associated with each waveform a number of other equally important specifications. For a sine wave output specify the total harmonic distortion as well as the maximum amounts of individual harmonics tolerable. Specify output voltage and if a DC component in the output is permissible. For a square wave output specify the rise time and fall time. The symmetry or duty factor should be specified as $50-50 \pm 10\%$ or whatever symmetry is required. Specify the output voltage in volts peak to peak and again include if a DC component is permissible. If neither a square or sine wave output is desired enclose a sketch depicting the exact waveform desired along with rise and fall times and desired voltage levels.

OUTPUT STABILITY: Specify the output stability desired and the temperature range over which this deviation may occur. It does not always hold true that the frequency stability and output stability are dependent on the same temperature range. Output stability may be a critical factor over a narrow temperature range while frequency stability is concerned with the overall temperature range. Specify the time for which this output stability has to be held and the maximum time the unit has to stabilize at a fixed temperature.

OUTPUT LOAD IMPEDANCE SPECIFICATION: If the load is entirely resistive, specify the value in the space provided. If the load is not entirely resistive specify the impedance in the space provided and include the percentages of inductive and capacitive components present. The specifications above are important, primarily the percentage of an inductive component present, since appropriate measures are taken to prevent damage to the output stage in the event of a "kick-back" from an inductive load. If the load is not constant specify the change in load and the rate at which the load changes. Depending on the output stability the change in load influences the source impedance of the output stage.

PULSE AND DIGITAL APPLICATION: When the oscillator is to be used in a digital system, specify if the output stage has to function as a current sink, that is, will the output stage have to absorb current as well as provide current? Specify the amount of current flowing into the output stage when it is functioning as a current sink. Indicate if the circuit is used to drive a capacitive load such as a bistable or monostable device by specifying the peak current and peak voltage as well as the triggering capacitance. If a pulse is desired specify the pulse width in microsec. When the oscillator is used to drive amplifiers, specify the "low" level as perhaps 0 volts to ± 0.5 volts and the "high" level as perhaps 8 volts ± 1 volt or whatever is required. The low level and high level can be any value consistent with the intended application. The polarity of the voltages are usually of the same polarity as the supply. Also indicate what DC component is desired if the low level is not "0" volts. Finally, indicate if the oscillator will be used in a portion of a system having NPN or PNP devices. This information is desired since it is far easier to drive an NPN flip flop with a NPN inverter.

PHYSICAL SPECIFICATION: Package size should be stated in maximum available dimensions in order to allow the manufacturer latitude in designing the smallest package consistent with the required performance. Airborne or space applications may have a stringent weight requirement and should be noted. Mounting of the oscillator to a chassis can be accomplished in a number of ways. Threaded inserts, studs, etc., should be specified to insure compatibility with the other system components.

Many engineers are amazed at the many parameters to consider in specifying oscillators. It is hoped that this brief explanation and specification questionnaire will be of help to you on your next oscillator requirement.

OUTPUT STABILITY SPECIFICATIONS

Output Stability: _____ % Temp. Range: _____ °C to _____ °C
Short Term: _____ min. or _____ hrs. Long Term: _____ hrs. or _____ days
Stabilization Time Maximum: _____

OUTPUT LOAD IMPEDANCE SPECIFICATIONS

Load: _____ Inductive: _____ % Capacitive: _____ % Constant Load: ☐ Yes ☐ No
If load is not constant, specify the following:
Range of Load: _____ Rate at which load changes: _____ % per _____

PULSE AND DIGITAL APPLICATIONS

Current Sink: ☐ Yes ☐ No If yes, specify current: _____ ma
DC Load: _____ ohms

TRIGGERING (AC LOAD)

Peak Current: _____
Peak Voltage: _____

SYSTEM LOGIC

NPN: ☐
PNP: ☐

Capacitance: _____ mfd. Pulse Width: _____ μ sec. DC Component: _____ volts
"Low" Level: _____ volts $\pm$ _____ volts / "High" Level: _____ volts $\pm$ _____ volts

PHYSICAL SPECIFICATIONS

Max. Size: _____ Max. Weight: _____

Termination: ☐ Octal socket
☐ P.C. board pins

☐ Hooked solder pins
☐ Special (describe)

Mounting: ☐ #6-32 studs
☐ Threaded inserts

☐ #4-40 studs
☐ Special (describe)

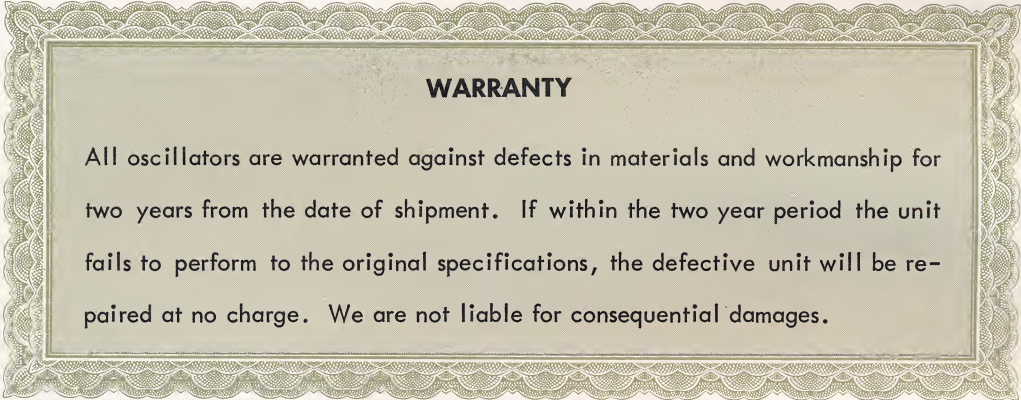
Finish: ☐ Paint ☐ Anodize ☐ Plated (tin) ☐ Other (specify)

QUOTING INFORMATION

Quantity: _____ Delivery Required: _____ ARO

Fwd. Quote to: _____ Copy to: _____

FOR HOME OFFICE USE ONLY		ACCUTRONICS REPRESENTATIVE
DATE RECEIVED _____	QUOTE NUMBER _____	
ENGINEER APPROVAL _____	DATE _____	
SALES APPROVAL _____	DATE _____	
PRODUCTION APPROVAL _____	DELIVERY _____	
QUOTE RELEASED _____	QUOTE CONTROL _____	

A decorative rectangular border with a repeating scalloped or lace-like pattern, enclosing the warranty text.

WARRANTY

All oscillators are warranted against defects in materials and workmanship for two years from the date of shipment. If within the two year period the unit fails to perform to the original specifications, the defective unit will be repaired at no charge. We are not liable for consequential damages.

